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The Use of Non-Conventional Water Resources as a Means of Adaptation to Drought and Climate Change in Semi-Arid Regions: South-Eastern Spain

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Abstract: Drought is a climatic risk with notable repercussions on water supply systems. The aim of this study is to analyze the principal measures for management and planning implemented during recent decades in south-eastern Spain (Segura River Basin) to respond to drought situations, focusing on the role played by non-conventional water resources (desalination and treated water). The results demonstrate that the study area (despite being one of the driest places of Spain) is less vulnerable to drought than regions with an Atlantic climate and greater availability of water. This has been possible thanks to the integration of non-conventional water resources as a means of adaptation to confront this natural risk, which is estimated to become more intense and frequent in the future owing to climate change.

Keywords: drought; desalination; treated water; planning; climate change; south-eastern Spain

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1. Introduction

Drought, considered to be one of the most important natural risks in some parts of the world and one of the greatest threats for society today [1–3], presents extensive negative impacts, which range from environmental to socio-economic aspects [4–7]. In Europe, comparison between the 1976–1990 and 1991–2006 periods shows a duplication of both the area and the population concerned by this natural phenomenon [8]. In this respect, it had already become apparent a decade ago that the number of people and regions affected by drought and water scarcity had increased by 20% between 1976 and 2006. The total cost associated with these episodes during those three decades amounted to 100 billion euros. For example, in the drought of 2003, one of the most intense, a third of the territory of the European Union and more than 100 million people were affected and its economic impact amounted to 13 billion euros [9].

In 2017, the Centre for Research on the Epidemiology of Disasters [10] published a report on the principal natural disasters that had occurred throughout the world during the first half of 2017. In relationship with economic damages, the report emphasizes that, of the ten most serious episodes, three correspond to droughts. The economic losses associated with this risk represented 38% of the total. In relationship with the population affected by natural hazards, droughts placed in first place. Of the ten most relevant episodes during the first half of 2017, eight were related to this risk, accounting for 66% of the population affected by these risks in the world (some 39.1 million people).

Drought has been considered an exceptional situation and the main instruments used to mitigate it have been reactive and emergency measures; that is, the construction of infrastructures to increase the supply of water resources and economic compensations for the damages and losses caused [11]. These initiatives, according to Wilhite [12], are included in what has been called the "crisis management focus", which has been shown to be insufficient to alleviate the effects of drought for the following reasons: (1) it limits the solutions to technical aspects. Its design does not include the evaluation of alternatives or the stakeholders' involvement; (2) it diverts attention to causes which provides that a decrease in precipitation generates shortages, and attributes their causality to the natural phenomenon without questioning the way in which the resource is managed and used; and (3) it produces a process of depoliticization that facilitates prioritization of technological solutions.

Subsequently, an alternative has been presented, the so-called "risk management focus", described as measures of a proactive nature and aimed at prevention and mitigation of drought impacts [12]. This measure focus on identifying where the vulnerability lies (sectors, regions, communities, or population groups) to implement measures for mitigation and adaptation to future droughts. Despite the advances deriving from this new focus, as Vargas and Paneque [13] indicate, drought continues to be one of the least-understood natural risks. The intrinsic complexity of the meteorological phenomena that govern the patterns of appearance of dry periods is accompanied by a series of characteristics that differentiate it from other risks and which pose considerable difficulties for its management. In this respect, as pointed out by Del Moral et al. [14], it is necessary to estimate and minimize its effects via ordinary water planning and coordination between the different sectorial policies (agricultural, spatial, and environmental) rather than having recourse to an exceptional route, such as drought orders. These hinder the application of the principles of prevention (anticipating the problems) and precaution, since they usually apply emergency procedures that do not facilitate the adoption of well-formulated and executed solutions. Furthermore, the drought risk is difficult to determine, since it depends not only on its duration, intensity, or geographical extension (variable of hazard), but also on the conditions of the society affected (vulnerability and exposure) [15] and its capacity to adapt and to confront this natural phenomenon [13]. As Vargas and Paneque [16] indicate, droughts may (or may not) produce situations of lack of water supply. This will depend on the level of demand and on the characteristics of the management and exploitation systems and access to the availability of non-conventional resources, such as desalination [17–21].

In Spain, during the second half of the twentieth century, the expansion of irrigated land, urban development, industrialization, the development of tourism activities, and hydroelectric power favored a sharp increase in demand for water, sometimes exceeding the natural supply of available resources [22]. This increase was accompanied by actions (transfers, reservoirs, and groundwater harnessing, mainly) aimed at increasing supply, which enlarged the risk of hydrological drought [23]. Thus, the lack of water infrastructure, the increase in consumption, and the precarious management of supply have extended their effects to regions theoretically well-endowed with resources, such as the Atlantic coast [24]. As Del Moral et al. [14] argue, unlike meteorological drought (which only takes into account precipitation in the affected area) hydrological drought is frequently the state brought about by a policy of continued increase in water supply.

The effects of climate change should also be added to these factors. In the Mediterranean Basin, not only is there an increase in average temperatures estimations, but also a reduction of precipitation or changes in the rainfall regime, which will intensify drought episodes [25] and the tensions relating to the water availability [26]. In this respect, the European Commission already considered in 2007 that the preparation of efficient drought risk management strategies should be considered a priority.

The solution to increase water volumes has been the incorporation of non-conventional resources (desalination and the reuse of treated water). Higher quality water (desalinated water) can be set aside for drinking water and that of lower quality (treated water) can be used for other activities that are less demanding, such as agriculture [27]. Given the progress made in water treatment, water can now be created depending on quality needs, with water management policies that are based on the "fit for purpose" concept [28]. Desalination has become a key water resource in arid and semi-arid areas [29]. In the Mediterranean Basin, for example, this resource is already considered an ordinary supply source in some regions, and especially in many islands. In Israel, for example, it has become the main source for urban supply [30]. Its use is also combined with inter-basin transfers, recycling, and diversification of fresh water away from agriculture [31]. Australia is another country characterized by diversification of water sources in order to achieve self-sufficiency [32], as is California (U.S.) [33].

The starting hypothesis is that the resilience of south-eastern Spain (Segura River Basin; study area) has changed with the incorporation of non-conventional flows. According to Holling [34], resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist. In this definition, resilience is the property of the system and persistence or probability of extinction is the result. Corroboration of this affirmation is considerably important for various reasons. Firstly, because the risk of drought in this territory will become more intense and recurrent according to the climate change scenarios [35]. In second place, because the study area is characterized by presenting water demands that exceed the supply. According to the Segura Basin Management Plan (2015–2021) [36], it is estimated at 400 hm^3/year. And lastly, it is an area that since the late 1970s has depended on water transferred from the Tagus River Basin via the Tagus-Segura Aqueduct (TSA) (600 m^3/year). Its future functioning will be compromised by the approval of more conservative management rules, an increase in demand in the donor basin, and the uncertainty of the effects of climate change [22]. The aims of this study are: (1) To analyze the main measures for management and planning implemented during recent decades in south-eastern Spain (Segura River Basin) to respond to drought situations, focusing on the role played by non-conventional water resources (desalination and treated water); and (2) to assess the level of resilience of this territory on the basis of the measures implemented, especially coinciding with the current drought of 2015–2018.

The structure of the paper is as follows. After the Introduction, which explains the problems and asserts the risks of drought at both an international and national level (Mediterranean region), the Methodology is described, together with consultation of the data. The Results are then presented, followed by the Discussions, which offers a debate regarding the strategic role that may be played by non-conventional water resources during drought situations, and lastly, the Conclusions.

2. Methodology

Methodologically, various documentary sources have been consulted, reviewed, and analyzed in relationship with the current situation regarding non-conventional water resources in order to assess their relevance as a means of adaptation to drought in the study area (Segura River Basin) (Figure 1). It is appropriate to indicate that, administratively, this area corresponds to a greater extent to the Region of Murcia and to a lesser extent to Castilla-La Mancha, the Valencian Community (province of Alicante), and Andalusia (province of Almeria). But it is in the provinces of Murcia and Alicante where demand is highest, due to the population supplied (2.5 million inhabitants, plus another million in the summer season as a result of residential tourism) and the irrigated land (147,276 ha).

First, the Segura Basin Management Plan (2015–2021) [36] was consulted. Specifically: (1) Data referring to the water resources available and those demanded; (2) those relative to the reduction of supply due to the effects of climate change; and (3) figures regarding the capacity and use of reclaimed and desalinated water.

Second, data on re-used water have been analyzed, provided by various organizations: The Spanish National Statistics Institute (last data available at national level; 2014) [37]; the water treatment companies (Entidad Pública de Saneamiento de Aguas Residuales—Public Entity of Wastewater Treatment of the Valencia Community—EPSAR) for the province of Alicante (2016) [38]; and Entidad de Saneamiento y Depuración (Entity for Wastewater and Sewage—ESAMUR) for the Region of Murcia (2012) [39]. Regarding data on desalination, information has been obtained from various sources: (1) Desalination plants managed by the Taibilla Canals Association (Mancomunidad de los Canales del Taibilla, MCT) (2003–2017) [40] (Plants of San Pedro del Pinatar I and II and Alicante I and II); and (2) desalination plants managed by Aguas de las Cuencas Mediterráneas (Waters of the Mediterranean Basins-Acuamed) (Águilas, Valdelentisco, and Torrevieja plants) (2017) [41].

Figure 1. Location and main land uses of the Segura River Basin. Own elaboration.

Third, data and documents have been analyzed relating to water resources and supply sources in the study area provided by the main users: (1) Urban users (Taibilla Canals Association—Mancomunidad de los Canales del Taibilla, MCT) [40]; and (2) agricultural users (Association of Tagus-Segura Aqueduct Irrigators—Sindicato de Regantes del Acueducto Tajo-Segura, SCRATS) [42]. Regarding the MCT, this is the main public organization that supplies water for urban uses: 80 municipalities belonging to the provinces of Murcia, Alicante, and Albacete and an area of approximately twelve thousand square kilometers.

In relationship with the SCRATS, this entity supplies water to 80,000 irrigators and a total gross area (that is, with allocation and the right to irrigate with water originating from the river Tagus) of 147,276 hectares, which enables 104,000 direct jobs. By regions, Murcia irrigates 85,397 ha with water from the TSA (57.97% and with an allocation of 260 hm^3/year), Alicante 58,878 ha (39.98% and an allocation of 125 hm^3/year), and Almeria 3000 ha (2.03% and an allocation of 15 hm^3) [43]. Lastly, transfers made by the TSA (1979–2017) have been consulted, given the relevance of these resources in the Segura Basin and their effects (reduction of the volumes transferred) in drought episodes.

3. Results

3.1. The 1992–1995 Drought: A Change in the Drought Management Paradigm

In Spain, due to its geographical location, drought episodes constitute one of the main natural risks of atmospheric origin [44]. Its effects and precipitation levels and the response by society are very different depending on the regions. The Balearic Islands, Canary Islands, and the territories corresponding to the Segura, Júcar, and Southern basins have demands close to or higher than the existing natural supply of resources. The largest consumers are present precisely where water scarcity is higher and where the territories are more exposed to drought, which is the case of South-eastern of Spain. The conventional resources provided by reservoirs, aquifers, and water transfers are those most exposed to drought situations [45]. In the light of this, the use of non-conventional resources (desalination and treated water) are presented as an alternative source and a means of adaptation to the increasingly scarce precipitation which may result from the effects of climate change.

One of the most intensive droughts of recent decades was that which occurred in the 1990s [45]. In its final stage (1995), 12 million inhabitants (more than 25% of the total population of Spain) suffered restrictions. The impact was especially intense in the east and south of Spain [46]. In cities such as Seville, evacuation plans were activated in view of the impossibility of guaranteeing minimum supplies to the population. Agricultural production suffered annual losses of between thirty and forty-two billion euros.

This drought episode (1992–1995) acted to trigger a change of conception with regard to drought management [45]. Until then, drought had been considered as an exceptional situation and as such the instruments used were characterized by their extraordinary nature. That is, priority was given to actions and policies aimed at generating a greater supply of water resources and economic compensations for the damages and losses caused without adopting measures to influence demand [47]. This period of low rainfall opened the debate on the focus on drought management as a process and on the need for efficient use and integrated planning of water resources. As Del Moral and Hernández-Mora [48] argue, this episode contributed, furthermore, to extending the idea that the water management system had, in some regions, reached a state of collapse.

The lack of water resources from conventional sources, the need to resolve the inter-regional conflicts associated with the TSA and the Ebro transfer (proposed in the PHN of 2001 and subsequently repealed) and, more recently, the threat to supply represented by the estimations associated with climate change are evidence of the need for a change in water policies. During the last century, the implementation of water transfers became one of the alternatives that generated the largest number of social and regional conflicts between donor and recipient basins [49]. Since its inauguration in 1979, the TSA (Figure 2) has become one of the hydraulic infrastructures that have given rise to the highest number of conflicts (political–social, environmental, and economic) between the donor basin during recent decades. The conflicts caused by transfers are directly related to a feeling of "unfairness" in the decisions regarding the allocation of water resources and, increasingly, to the defense of the environmental and heritage values of the donor basins [50].

Figure 2. Routing of the tracing of the Tagus-Segura Aqueduct and main reservoirs of the Segura River Basin (own elaboration).

Related to climatic change, as indicated by Olcina [44], the situation with regard to access to water resources may worsen even further according to the estimations for a reduction in rainfall and an increase in the irregularity of rainfall referred to climatic modelling. This has been corroborated by various authors who point to a clear change in precipitation patterns in the last twenty years in the south-east of the Iberian Peninsula (reduction of 0–15%), an increase in dry periods, and a reduction in rain-days [26]. CEDEX (Centre for Public Works Studies and Experimentation) [51] has drawn up a report on the effects of climate change on water resources in Spain, which is based on the study of 12 regionalized climate projections prepared by the State Meteorological Agency [35]. These ones had been drafted attending the Spanish Office for Climate Change (OECC) recommendation, which noted the need to use projections of RCP 8.5 and RCP 4.5, based on the recent evolution of greenhouse gas emissions in the forecasts of the Paris Summit, 2015. For Spain as a whole, decreases in water resources are reported between −7% (RCP 4.5) and −14% (RCP 8.5) for the 2070–2100 horizon. However, in the Mediterranean basins the estimated resource reduction is between 11% and 15% (RCP 8.5) (horizon 2040). Also, the recent study of the IPCC [25] stated that in the Mediterranean basin the decreases in water resources will be 11% due to the increase of 1.5 °C by 2060.

Therefore, these scenarios should be taken very much into account to adapt these territories to droughts and reduce their vulnerability to the decrease in water supplies [16]. In Spain, in the last three decades a decline has already been recorded in the average annual intake (hm^3/year) in all the river basin districts. Comparing average values for the 1996–2005 period with that of 1940–1995, this increases to 14.3% for the country as a whole. Percentages of over 20% are recorded in the river basins located in the southern half of mainland Spain and on the Mediterranean coast. In the Segura Basin, the reduction has been 38.2% (from 817 to 505 hm^3/year), the largest decrease of all the Spanish river basins [52].

In the Segura Basin, according to the 1998 Management Plan, total demand amounted to 1932 hm^3/year, with agricultural demand being the highest (86%). This was reduced to 1779 hm^3/year in the 2009 Management Plan. The falling trend has continued to date. According to the Management Plan in force (2015–2021), current demand is 1726 hm^3, with a total deficit of 400 hm^3/year (Table 1). This one gains considerable relevance due to the hectares of irrigated land. In the Region of Murcia, it represents 54% of the total cropped area, whilst in Alicante it amounts to 84%. According to future projections (2033 horizon), it is estimated that the total demand will increase slightly (2.14%; 37 hm^3) to 1763 hm^3 as a consequence of the enlargement in urban demand, which will rise from 189.1 to 210 hm^3 (11%).

Table 1. Current and future demands in the Segura River Basin (hm^3/year).

Demand	Urban	Agricultural	Industrial Not Connected	Golf Courses	Environmental Flows	Total
2015 horizon	189.1	1487.1	9.1	11.3	29.6	1726.5
2021 horizon	194.3	1487.1	9.5	11.3	29.6	1731.8
2027 horizon	208.3	1490.9	10.3	11.3	29.6	1750.4
2033 horizon	210.9	1490.9	11.5	20.6	29.6	1763.5

Source: Segura River Basin District [36].

3.2. The Adoption of Desalination

The adoption of desalination has been considered the most appropriate alternative supply to stabilize water balances in the Spanish deficit basins. On the one hand, it would put an end to the inter-regional conflicts and social tensions generated around the construction of water transfers [14]. On the other, it represents an efficient measure in light of the scarcity of resources in the Mediterranean regions, accentuated in periods of drought, thanks to the availability of a resource (sea water) that is independent from the climatic conditions [19,21].

One of the first initiatives adopted in the Segura Basin was the Plan for the Use and Distribution of Treated and Salt Water (Plan de Aprovechamiento y Distribución de Aguas Depuradas y Salinas, PAYDES) (1995) incorporated in the drought plan, Plan Metasequía of 1995. Its aim (emergency action), which arose from the water shortage suffered in the south of Alicante as a consequence of the intense drought of the 1990s, was the construction of 16 plants with a total production capacity of 16.2 hm^3/year to irrigate some 10,000 ha of the Pedrera Irrigation Area (South of Alicante) [53].

Five years later, the approval of Law 10/2001 of the National Hydrological Plan included numerous actions with regard to the supply of drinking water. Although the majority had a decidedly hydraulic profile (investments for new reservoirs, catchment, and transportation pipelines, potabilization, and treatment stations) it also contemplated the reuse of wastewater, inter-basin water transfers, and desalination. Regarding this latter resource, for example, in the Segura Basin, it included the construction of 5 new plants (Campo de Cartagena, Murcia, Alto Guadalentín, La Pedrera and Pilar de la Horadada), 2 new brackish water plants in the Vega Baja and the Guadalentín, and the enlargement of the plants of the Taibilla Canals User Community (Mancomunidad de los Canales del Taibilla, MCT) [53].

In 2004, the approval of the A.G.U.A. Program (Actions for the Management and Use of Water) [54] (a basic component in the reform of the state water policy driven by the Law 11/2005 of 22 June which amended the Law 10/2001) opened a new stage in water planning and the generation of desalinated water in Spain, which received the largest boost to date. One of the central features of this program was the replacement of the 1050 hm^3/year contemplated in the repealed Ebro Transfer with resources provided by desalination. The program, initially budgeted at 1.191 billion euros and with an execution period of four years, guaranteed, together with the desalination plants and other actions to improve water infrastructures, the water resources necessary for the MCT supply. In the case of the province of Alicante (territory divided between the Júcar and Segura basins), the actions were based on the increase of 190 hm^3/year with the construction of desalination plants in the Marina Alta, Marina Baja, Jávea, Alicante, Vega Baja, La Pedrera, and Pilar de la Horadada. In the Region of Murcia, the majority of the plants proposed had already been scheduled in the PHN of 2001 (desalination plants of Valdelentisco and San Pedro del Pinatar II). As such, this hydrological plan did not include the construction of a desalination plant to guarantee the irrigation from the TSA, which the A.G.U.A. Program situated in the Region de Murcia, although it corresponds to the Torrevieja plant (80 hm^3, 40 hm^3 for irrigation and 40 hm^3 for supply urban areas). This, completed in 2010, replaced two other desalination plants that the PHN located in La Pedrera and Pilar de la Horadada, on the border of the provinces of Alicante and Murcia [53] (Figure 3).

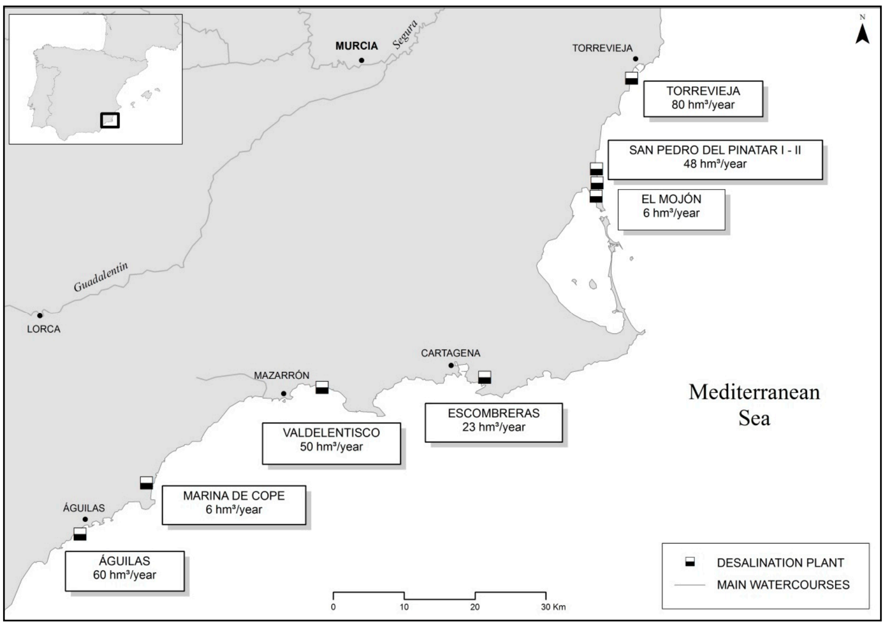

Figure 3. Location of the desalination plants of the Segura River Basin (own elaboration).

At the end of 2017, according to the Spanish Association of Desalination and Reuse (Asociación Española de Desalación y Reutilización, AEDyR), Spain had some 900 desalination plants. These plants are for both brackish and sea water, with a production capacity ranging from 100 to over 100,000 m^3/day and reaching a capacity of approximately 1.2 million m^3/day (438 hm^3/year), of which 700,000 m^3/day corresponds to the desalination of seawater (58.33%) and the rest to brackish water (aquifers). In the Segura Basin, the maximum production capacity for desalinated water was 332 hm^3/year for the 2015 horizon and 339 hm^3/year for the 2033 horizon, from a total of 13 plants. However, the total production is somewhat lower at 158 hm^3/year for the 2015 horizon and 224 hm^3/year for 2033 (Table 2). Furthermore, it is appropriate to indicate that desalinated resources (a total of 48 hm^3) from the Júcar Basin (Alicante I and II plants; managed by the MCT) can be used.

Table 2. Situation of the main desalination plants in the Segura River Basin District.

Plant	Year of Construction	Irrigation Volume (hm^3)	Supply Volume (hm^3)	Current Status
Torrevieja	2010	40	40	Functioning since August 2015 to palliate the drought and the reduction of the Tagus-Segura transfer. Production of subsidized water at 0.30 €/m^3 during 2016–2017. Currently producing 50% of its capacity for urban supply due to lack of power supply.
Águilas	2011	48	12	Functioning at 90% mainly for agricultural uses.
El Mojón Brackish Water Desalination plant for irrigation runoff	2006	6	0	In service.
Escombreras	2009	0	22.9	Without demand for urban-tourism uses
Marina de Cope (Águilas)	2006	6	0	In service
Valdelentisco	2008	0	50	Functioning at 61% (urban and agricultural uses)
Virgen de los Milagros (Mazarrón)	1998	10	0	Functioning continuously during the months of July and August. The rest of the year it works at weekends.
San Pedro del Pinatar I	2006	0	24	Functioning at 95%.
San Pedro del Pinatar II	2008	0	24	Functioning at 71%.

Source: Morote et al. [21]. Mancomunidad de los Canales del Taibilla [40]. Acuamed [41]. Own elaboration.

The highest production capacity for desalinated water is concentrated in the area served by the MCT (plants of San Pedro del Pinatar I and II, and Alicante I and II) with 96 hm^3. However it should be indicated that since water production commenced (2003 with the Alicante I plant) to date, the maximum volume of resources has never been reached. Its production is influenced by the availability of other resources, especially those originating in the river Taibilla and the TSA. Since desalinated water has been supplied (2003), water originating from the TSA represents 48.74%, and desalination 20.25%. Thus, during the 2013–2014 period in the MCT only 6.2 and 11.2 hm^3 of desalinated water was produced, since the supplies from the TSA and Taibilla were abundant. Its production has increased during recent years due to the cuts in this transfer as a consequence of the drought.

During the current drought in the south-east of Spain (2015–2018), the worst period related to water supply was May 2017–March 2018 (Figure 4), a period in which the TSA was closed since the reserves in the headwaters of the Tagus were below the non-transfer threshold (400 hm^3) [22]. In this period, the desalination represented approximately 60% of the water supplied by the MCT (Figure 5). Additionally, 2017 was the year in which the most desalinated water was produced (85.3 hm^3) of the 96 hm^3 possible (88%) up to now. Desalinated resources represented 44% of the total, compared to transfers from the TSA, which amounted 18.74%. The Figure 5 shows the evolution of MCT supply sources since 2003, when desalination is incorporated for urban supply.

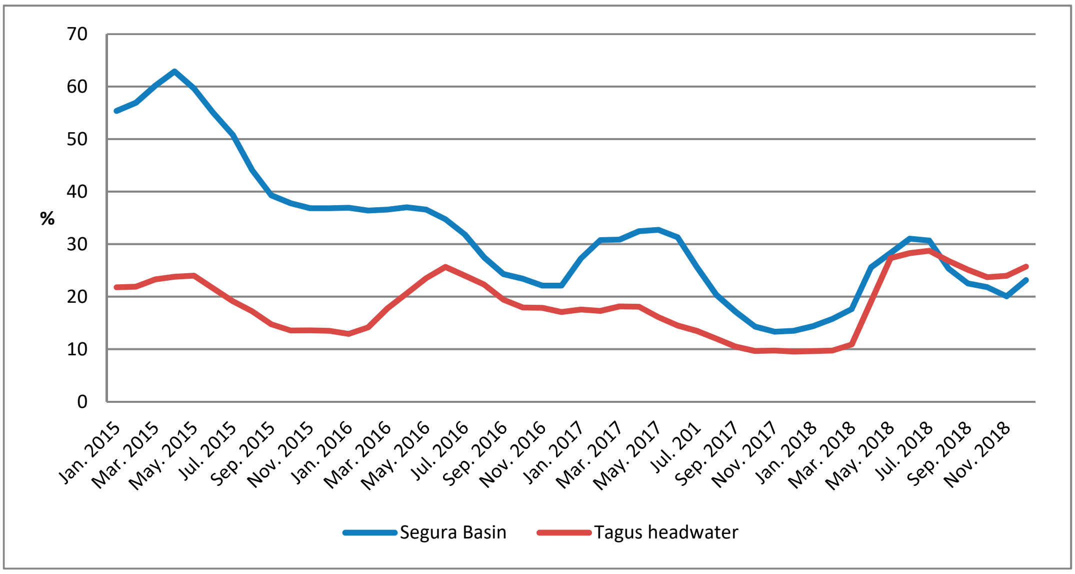

Figure 4. Water stored (%) in the Segura Basin and in the Tagus headwater (January 2015–December 2018) Source: Ministerio para la Transición Ecológica [55]. Own elaboration.

The incorporation of desalinated water has notably reduced the drought threshold for urban uses in the Segura Basin. That is, desalination has allowed: (1) A substitution of sources; (2) decrease dependence on water surface resources as rainfall and transfer; and (3) increase the adaptation and resilience of the study area to drought in the availability of water resources. This driver can even increase, since a number of desalination plants are either not operational (Muchamiel) or operate at a low level. During the drought of 2015–2018, and specifically during the period when the TSA was closed, its transfers were replaced by desalinated water, satisfying without problems the demands for urban (and in some cases agricultural) uses and avoiding cuts in supply and restrictions. Its generalization as a substitute resource for the transfers from the TSA will be accentuated in the medium and short term as a consequence of the reduction of the intakes from the headwaters of the Tagus in light of more frequent drought episodes, increasing the demand in the headwaters and management rules that are more conservative and fairer for the donor basin [22].

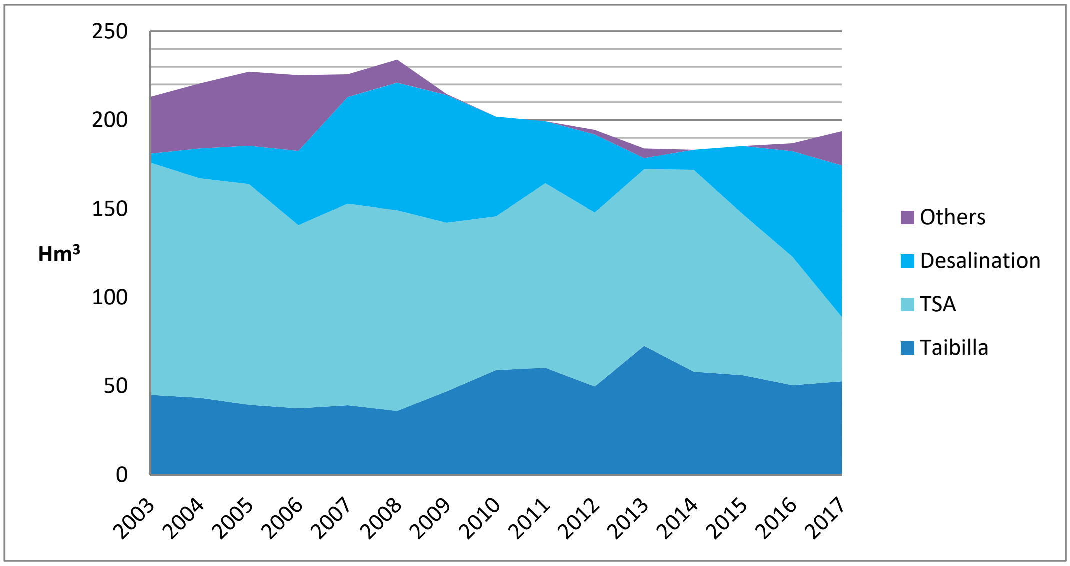

Figure 5. Supply sources of the MCT (hm^3) (2003–2017). Source: Mancomunidad de los Canales del Taibilla [40]. Own elaboration.

Another different matter is the farming sector for which water from desalination continues to have, at present, too high an economic cost to be integrated as an ordinary water resource. In 2017, the Central Association of Tagus-Segura Aqueduct Irrigators (SCRATS) [42] prepared a report on actions in the short, medium, and long term to solve the shortage of water resources during the current drought. They determined that if the irrigated area continues to be the same (147,276 ha) and with the same allocation (209 hm^3/year originating from the river Tagus), a volume of 205 hm^3/year would be necessary [51]. In order to satisfy it, the measures include: (a) Increase of production in the existing desalination plants in the Segura Basin (Torrevieja, Valdelentisco and Águilas) (A.G.U.A. program) [54], which could mean in a first phase an additional volume of around 70 hm^3/year compared to current production; (b) enlarge the capacity up to the maximum contemplated in the Segura Basin Management Plan (2015–2021) [36]. That is to say, an increase of 140 hm^3/year compared to current production, reaching a total of 260 hm^3/year; and (c) the available production of the plants of Acuamed that have not been earmarked to its demand will be allocated to cover the current deficit. Furthermore, it should not be allocated to new demands not considered in the aforementioned Basin Plan.

3.3. The Use of Treated Water

Treated water has become an alternative to supply certain types of consumption and expand the supply of water resources. This interest increases, especially, coinciding with episodes of drought, since the pressure on conventional resources is reduced, a fact that has allowed a greater margin for maneuver to guarantee the supply of drinking water. The considerable development of these resources since the end of the twentieth century is due to: (1) Compliance with the Water Framework Directive (WFD 2000/60/EC); and (2) the Community Directives 91/271/EEC and 98/15/EC on the treatment of urban wastewater, which oblige wastewater to be treated before being discharged or reused.

In Spain in 2010, according to data of the Ministry of the Environment and Rural and Marine Affairs reflected in the National Water Quality Plan, the volume treated exceeded 3300 hm^3 and there were more than 2533 Wastewater Treatment Plants (WWTP). Andalucía (545 treatment plants; 21.5%), Catalonia (281; 11.1%), and the Valencian Community (270; 10.6%) were the autonomous communities with the greatest number of facilities. According to Olcina and Moltó [17], in that year, in theory, more than 4500 hm^3/year of water was treated, although its effective use (reuse) was limited to just 450 hm^3 (10%). According to the latest data available from the National Statistics Institute, in 2014, the volume of treated water amounted to 4942 hm^3, but only 530 hm^3 (10.7%) was reused. These figures contrast, for example, with Malta and Cyprus, where practically 100% of treated water is reused. However, notable regional differences can be observed. 25% of all the volume reused in Europe is used in the Valencian Community and the Region of Murcia (Spain) (Table 3). Its use, as happened with desalination, increases the resilience of the territory to the risk of drought. It allows for creation of flows for agricultural uses that require lower quality and at a lower cost than surface resources or desalinated flows. These data are very different from the estimations considered at the World Congress on Desalination, organized by the International Desalination Association (IDA) in Gran Canaria (Canary Islands, Spain) in 2007, which indicated that Spain would triple its reuse capacity in 2015 to reach 1200 hm^3/year [56]. With regard to allocated uses, in Spain, 61.3% is destined for agriculture and it is emphasized that, in recent years, there has been an increase in the percentages destined for environmental uses and the watering of gardens (18.5%) and industrial uses (8.2%).

According to the latest data available in the Segura Basin Management Plan (2015–2021) [36], in 2012 the municipal urban wastewater treatment plants (a total of 206) treated 140.1 hm^3, of which 78.2 hm^3 was reused directly (55.82%) and practically all the rest indirectly (water discharged into the river Segura, which is subsequently reused). The analysis on a provincial scale (Alicante and Murcia) reflects the relevance of these resources in both provinces. In Murcia, the percentage of direct and indirect reuse, as has already been commented, amounts to almost 100% (110 hm^3). In Alicante, in 2016, there were 164 treatment plants which treated 122.8 hm^3, of which 59.7 hm^3 were volumes reused directly (48%) and 27.4 hm^3 indirectly (22.3%) [38]. This means that there is a possibility of potentially reusable water of 35.7 hm^3 (29%), although this percentage of “non-reuse” is due to: (1) the fact that not all the water treated is of a quality acceptable for irrigation; and (2) to the absence of infrastructure and distribution and regulation networks that allow its subsequent reuse. In Alicante, of the 164 treatment plants, only 13.4% have tertiary treatment (22 plants). Added to this is the salinity of the water treated, which certain crops do not tolerate, necessitating the incorporation of an advanced treatment that includes desalination (reverse osmosis). In this respect, just 3 plants offer desalination: Alicante (Rincón de León), Benidorm, and Aspe. By region, treated water is used most in the Bajo Vinalopó (97.5%), Alto Vinalopó (87%), and the Vega Baja (85.7%), dropping to 33.5% in l’Alacantí. It is precisely in these regions where there is a greater volume of treated water and where the plants with greatest production capacity are located and which include tertiary treatment (treatment of 81.6 hm^3; 67% of the total). The lowest percentage of reuse (the great majority with secondary treatment) is in the inland and mountain regions, which in turn do not have a water deficit. As noted for the desalination, the incorporation of these flows in the medium and long term could increase the adaptation capacity of these territories by reducing the pressure on water for urban uses.

Table 3. Volume treated and reused in Spain per Autonomous Community (2014) (hm^3).

Autonomous Com.	Volume Treated	Volume Reused	% of Water Reused
Andalusia	732.1	57.3	7.8
Aragón	201.6	1.5	0.7
Asturias	201.5	13.9	6.9
Balearic Islands	122.3	55.6	45.5
Canary Islands	139.6	27.7	19.8
Cantabria	97.4	1.9	2.0
Castilla y León	390.6	3.9	1.0
Castilla-La Mancha	192.7	5.5	2.9
Catalonia	629.6	25.2	4.0
Valencian Com.	419.8	248.9	59.3
Extremadura	162.1	55.1	34.0
Galicia	330.1	0.4	0.1
Madrid	613.8	14.5	2.4
Murcia	132.8	66.8	50.3
Navarra	78.8	0.0	0.0
Basque Country	425.9	6.7	1.6
Rioja, La	54.0	0.0	0.0
Ceuta & Melilla	16.6	0.1	0.6
Spain	4942.0	530.7	10.7

Source: National Statistics Institute [53]. Own elaboration.

4. Discussions

4.1. Desalinated Water: A Strategic Resource during Drought Situations

Desalination is already a reality on much of the Mediterranean coast and it has even acquired the label of an ordinary supply source. Various authors have debated the role that may be played by desalination in water policy [14,20,21,57–59]. As Baldwin and Uhlman [60] affirm, desalination may contribute to improving water security and it may become a secure source of long-term resources, with the flexibility that its production can decrease in the event of abundancy of other sources and increase in the case of drought episodes. In this respect, Del Moral et al. [14] explains that the installed desalination capacity should be used as a tool for rapid response that would allow an increase in a short time of the water generated to attend to the strategic needs threatened in a drought situation. This would require the installed capacity to work in non-drought periods at a high, but not maximum, level. Thus, during situations of scarcity, the maximum capacity could be activated.

The current situation of drought in the Segura Basin is being faced with all the desalination plants of the A.G.U.A. in operation, with the exception of Torrevieja. This last plant can only produce half of its production capacity due to lack of energy supply (around 40 hm^3/year). Until the re-opening in April 2018 of the TSA, the MCT plants supplied around 60–70% of the resources available in costal municipalities. During the worst months of the drought in south-eastern Spain, thanks to desalination, there were no water supply cuts in urban areas. However, in the 1992–1995 drought, supply cuts were suffered because there were no desalination plants. Besides which, desalination takes on such an important role that it is even contemplated as an emergency resource to be transferred to other regions that do not have "direct" access to this resource. Such is the case of the Muchamiel plant (Júcar Basin). Built in 2012 (with a 18 hm^3/year capacity of production), it operated between summer 2015 and autumn 2016. During this period, it supplied 10.8 hm^3 to the region of the Marina Baja (mainly to the tourist city of Benidorm) through the Rabasa-Fenollar-Amadorio emergency channel.

Therefore, it can be affirmed that the Segura Basin is an area less vulnerable to drought than a few decades ago and compared to other Spanish regions where the average rainfall exceeds 1000 mm/year. This is what has happened, for example, during the current drought in Galicia (Northwest of Spain), in which serious supply problems have been suffered for population and livestock uses. In Galicia, until the winter and spring rains of 2018, many towns and farms suffered supply restrictions. They were supplied by tanker trucks and water withdrawals from emergency wells. In this area, the main causes that aggravated the drought were: (1) scarce efficiency of the water supply network (below 70%); (2) Lack of infrastructure and its maintenance. The reservoir capacity for consumption amounts to 63.62 hm^3 (only the 9.2%) and water catchment is produced directly from the rivers, which dried or had flow rates below those catchments; and (3) the impossibility of accessing the water stored in the reservoirs destined for hydroelectric production, which adds up to a capacity of 626.54 hm^3 (91.8%) [61].

The production of desalinated water has been considered by the Intergovernmental Panel on Climate Change (IPCC) as a resource with great potential to propose adaptive strategies against climate change, particularly in areas characterized by aridity [21]. These non-conventional resources could contribute, as indicated by Baldwin and Uhlman [60], to increase water security to become a robust source of supply. In addition, it is possible to modulate its production to the extent necessary, taking into account supply fluctuations experienced by conventional resources by climatic and hydrological conditions subject to periods of intense and prolonged drought.

The defenders of desalination argue that it may be the solution to supply problems on the Mediterranean coast and perhaps the key to facilitate the supply to new urban growth [62]. It may also become a resource that does not depend on climatic conditions, or on the variations in availability offered by surface water resources [30]. Furthermore, it could put an end to the political, social, and inter-territorial conflicts generated by water transfers between recipient and donor regions [63].

However, some authors, such as Morote et al. [21], explain that desalination is not the panacea for water scarcity, but it is a strategic resource to mitigate water insufficiency during drought situations. According to Morote et al. [53], when analyzing the advantages and disadvantages offered by desalination, it is necessary to take into account the environmental and socio-political costs (end of inter-territorial conflicts), the economic costs (price of water), and energy consumption [64]. The use of this resource has led to an increase in the price of water in recent years. This is the case, for example, of the water supplied during 2015 and 2016 from the plant of Muchamiel to the Water Consortium of the Marina Baja (province of Alicante). This "emergency" supply entailed an increase of 27.7% rising from 0.36 to 0.46 €/m^3. In the case of the area served by the MCT, during the period that the TSA was closed, the increase was of 21% (from 0.69 to 0.83 €/m^3) [65]. In this scope, it increased by 91% (from 0.36 €/m^3 to 0.69 €/m^3) between 2005 and 2017, respectively, as a result of the commissioning of different desalination plants (Alicante I and II and San Pedro del Pinatar I and II).

Regarding energy consumption, this has decreased from 22 kWh/m^3 in 1970 to less than 4 kWh/m^3 in 2018. However, these data differ between plants and depending on the installed capacity and production. For example, in Águilas and Torrevieja plants, consumption is 2.3 and 2.9 kWh/m^3, respectively, although the average in the plants of the MCT is 3.2–4.8 kWh/m^3 [21].

Despite this significant advance with regard to energy efficiency, desalination is still far from reaching the consumption figures offered by other resources in the Segura Basin: 1.1 kWh/m^3 and 0,09 €/m^3 (water from the TSA), 0 kWh/m^3 and 0,03 €/m^3 (Taibilla river), or groundwater (1 kWh/m^3 and 0,20 €/m^3). To reduce this consumption, different options have been considered, among which it is appropriate to mention the use of solar photovoltaic power, which could reduce the cost of production by 40%, or the integration of the desalination plants in a global water management system. In this way, desalination would form part of a "water mix", including surface water resources, groundwater, and reclaimed wastewater, which would be consumed and allocated to the different uses according to criteria of availability, quality, cost, and guarantee of supply [56].

4.2. Treated Water: A Potential Resource but with Still Disadvantages

The use of treated water constitutes an alternative source of extraordinary interest to mitigate the natural scarcity of water and the effects of drought. Its use allows the freeing of higher-quality water resources to guarantee priority uses, as well as adaptation of the quality of the water resource to the final use [28]. In regions with high vulnerability to droughts and with problems of water scarcity, such as the study area, the reuse of treated water has been consolidated during the last two decades to guarantee agricultural, urban (gardens and washing of streets), recreational (golf courses), and industrial supplies. This has been favored by an improvement in treatment technologies, by means of advanced tertiary treatments that include desalination. This has allowed the Segura River Basin District to become the only Spanish river basin district where almost 100% of wastewater is treated and reused [17], thus reducing dependency on the water of the TSA.

On a local scale, it is appropriate to quote the example of the use of treated water in the city of Alicante. Since the implementation of the Reuse Plan (2002), treated water has been supplied for both municipal uses (watering of gardens and public parks and washing of streets) (Figure 6) and for private uses (mainly for watering the gardens of private houses). In 2002, the use of this water amounted to a volume of just 39,358 m^3 compared to 1,141,556 m^3 in 2017, of which 57.80% is supplied to the council (659,802 m^3) and the rest to individuals (481,654 m^3). In 2017, the treated water in Alicante represented 4.79% of the total drinking water supplied. This has allowed approximately 80% of the green zones of the city to be maintained with treated water (446 ha), a process which, as well as representing economic, energy, and environmental savings, has made it possible to triple in the last ten years the area dedicated to parks and environmental areas.

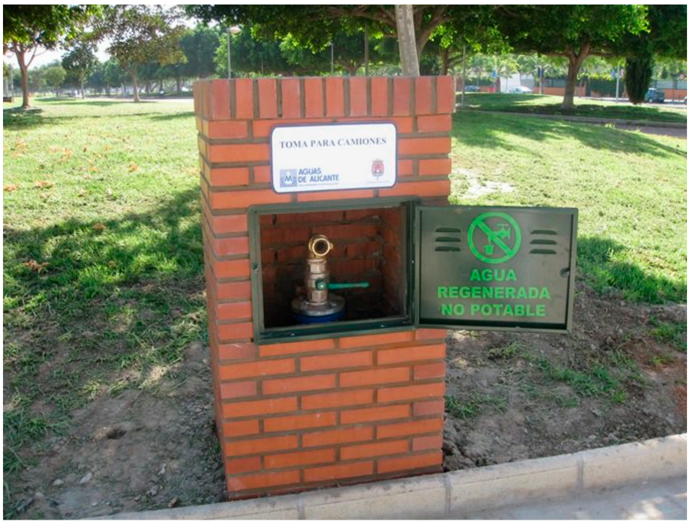

Figure 6. Treated water hydrant (city of Alicante, 2018). Source: Picture by the authors.

The reuse of treated water is considered one of the practices best adapted to the principles of sustainable development [66], although its use is limited by regulations and by the social rejection of its use for domestic purposes for health reasons [67]. Treated water should play a greater role in the overall water resources available, for both agricultural and urban-tourism uses. Wastewater treatment plants should be improved until they reach an optimum level of purification for agricultural use. This entails the making of investments that include advanced treatments and the desalination process of the treated water, in order to prevent the rejection to which its use is still subjected by traditional agriculture. In cities, bylaws should be approved that impose the use of treated water for the watering of parks and urban gardens and replace drinking water for these uses ("fit for purpose") [28]. The decrease in drinking water consumption with the replacement of uses and its use in agriculture allows the entry of new resources into the water cycle. This allows the water to be kept longer in the cycle. In this way, on the one hand, a more sustainable use of water is promoted through the adoption of practices associated with the circular economy, and on the other hand, the resilience of these territories is encouraged in the face of the risk of drought.

4.3. Changes in Water Paradigm

In Spain, significant institutional changes have taken place that point to a change in focus of the water paradigm [48]. The efficient use and integrated planning of all the available water resources would be associated with the incorporation of non-conventional resources, mainly desalinated water and treated water [21]. However, in relationship with desalination, some authors argue that the A.G.U.A. program is a continuation of the traditional policy of increased water supply, in this case via desalination as an alternative to transfers [22].

Despite this, and especially after the entry in force of the WFD 2000/60/EC [68], a slow transition can be seen in water policy. The WFD involved several novelties in terms of concepts and conception of water as a resource and its management. On the first question, it means: (1) the introduction of the concept of environmental status of surface water bodies. It becomes a priority issue; (2) the inclusion of all water bodies, both continental (surface and underground), transitional and coastal, and associated ecosystems; and (3) a holistic and eco-systemic vision of water, understood not as a mere economic resource, but as a carrier of social, environmental, and cultural values.

From the point of view of management, it establishes: (1) the adoption of measures aimed at the sustainable management of the resource. It advocates the replacement of traditional hydraulic policy (generation of resources) with others oriented to demand planning; (2) the incorporation of the principle of recovery of water uses, which include the environmental costs associated with the damage or negative impact caused in the aquatic system according to the polluter pays principle; and (3) public participation. As Martínez [69] indicates, the great objection faced in some regions by the National Hydrological Plan (PHN) of 2001, (and more specifically the Ebro transfer) was possibly the trigger that enabled the creation of the New Water Culture movement. This movement arose at the beginning of the 1990s in response to centralized water management, based on an increase in supply via large hydraulic infrastructures and water transfers. In the light of what is known as the water paradigm, a new focus was provided, based on demand management and the search for sustainable alternatives—from the environmental, social, and economic point of view—to conventional water resources.

Regarding the measures to mitigate the effects of drought, in addition to non-conventional water resources, measures for demand management should be encouraged and favored. Furthermore, it is appropriate to consider the regulations and drought plans made by the authorities to manage these episodes, and especially a regulation of such phenomena. Finally, it is appropriate to point to the importance of environmental campaigns that, especially coinciding with drought episodes, become a measure of great interest for the dissemination and awareness among the population of the importance of responsible water consumption. It is the ideal way to convert the cities of south-eastern Spain into resilient cities in view of the risk of drought [44].

It is necessary, likewise, to favor the circular water economy and to promote resilient agriculture in the light of the variability inherent to the Mediterranean climate and in view of climate change, reducing the demands not only with greater efficiency (less consumption per hectare) but decreasing total consumption, going from a quantity to a quality model. In this respect, Del Moral [70] affirms that the contention and reduction of demand would make it possible to: (a) Reduce the exposure and vulnerability of the population and the production sectors when drought arrives; and (b) generate unused reserves, which can be mobilized in a drought situation.

5. Conclusions

The Segura Basin is a less vulnerable region to drought than a few decades ago. The measures implemented in recent decades (use of non-conventional water resources, changes of water paradigm, measures to manage the demand, and the implementation of drought plans) in south-eastern Spain to mitigate the effects of drought has increased its resilience to this hazard. One of the conclusions drawn in this research is the importance and role of non-conventional water resources. Especially, during drought situations and their extreme importance in achieving territories that are more resilient to climate change, not only during dry periods but also as an available resource to take into account during normal rainfall years. In periods of normal rainfall, demand management (reduction of urban and agricultural consumption) has also been shown as a measure aimed at adapting to the drought of this territory.

Desalination has not only become a strategic water resource of vital importance during drought situations, but it is increasingly configured as an ordinary source for urban supply in coastal areas of the European Mediterranean [21]. During the current drought situation (2015–2018), all the desalination plants of the A.G.U.A. program in the Segura Basin have become operational, with the exception of Torrevieja, which can only produce half of its capacity due to lack of power supply (some 40 hm^3/year). The plants of the MCT, during the period that the TSA was closed, supplied around 60–70% of the resources demanded in the coastal and pre-coastal sector of the provinces of Alicante and Murcia. Thanks to this, on the coast of south-eastern Spain, there have been practically no restrictions in urban supply during this period, unlike the drought of the 1990s [46]. One of the reasons for them in this last period was due to the non-existence of the non-conventional water resources (desalination and treated water) [45]. It must be also noted that its promotion and generalization as a substitute resource for TSA transfers will be increased in the future. This is because more and more, the contributions from aforementioned transfer will be reduced by episodes of drought and the new conservative exploitation rules for the ceding basin.

The use of re-used water for agricultural and urban uses has allowed, on the one hand, has reduced the pressure on fresh water, and on the other, encouraged a more sustainable use of water resources by incorporating them into the water cycle. According to the Segura Basin Management Plan (2015–2021), urban wastewater treatment plants treated 140.1 hm^3, of which 78.2 hm^3 was reused directly (55.82%) and practically all the rest indirectly (water discharged into the river Segura which is subsequently reused).

Despite being the most region arid in Spain and with a natural scarcity of water, the endeavors undertaken in this territory make it one of the best adapted to water scarcity. Even with the increase in resilience, it is necessary to be critical and change the perception of the exclusive dependence on TSA transfers in the south-east of Spain and think about a new approach and integrate all available water resources. The TSA should be considered as another source and it should be taken into account that it will be an unavailable resource coinciding with years of drought in the headwaters of the Tagus. Therefore, all available resources should be integrated into a water mix (own resources, surface, underground, water from the TSA—when it will possible, desalination, and treated water) and should be developed and given more importance in water policies from the perspective of management of the demand and a more efficient use of resources.

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